Journal of Cereal Science 72 (2016) 146–152

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Milling and extrusion of six barley varieties, effects on dietary fibre and starch content and composition

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ARTICLE INFO

Article history:
Received 23 May 2016
Received in revised form
26 September 2016
Accepted 30 September 2016
Available online 1 October 2016

Keywords:
Barley
Extruded
Dietary fibre
β-glucan

ABSTRACT

Barley is a rich source of dietary fibre that can promote beneficial physiological effects. The carbohydrate composition in different barley varieties differs considerably and choice of variety is thus important. This study examined whether differences in carbohydrate composition observed in barley kernels of different varieties persisted in the sifted flour and in an extruded product. Six barley varieties were milled and extruded and dietary fibre and starch in the kernels, flour and extruded product were analysed. The starch content was found to be higher in flour and extruded product than in kernels. The content of arabinoxylan was higher in sifted flour than in kernels, but was decreased by extrusion. The extractability of arabinoxylan was increased by extrusion, while its average molecular weight was decreased. Extrusion also decreased the content of mixed-linkage (1 → 3),(1 → 4)-β-D-glucan in all varieties, but increased its extractability. The six barley varieties were affected in much the same way by milling and extrusion, but clear differences could still be observed. For example, the arabinoxylan in variety SW 28708 was less affected and variety KVL 301 had much lower extractability (76% vs 91–98%) of mixed-linkage (1 → 3),(1 → 4)-β-D-glucan after extrusion than the other varieties.

1. Introduction

Barley (*Hordeum vulgare* L.) is an ancient crop that is currently mostly used for animal feed and brewing, but is gaining attention as a human food crop. This is partly because of its high content of dietary fibre and in particular of mixed-linkage (1 → 3),(1 → 4)-β-D-glucan (β-glucan), which has an EFSA-approved health claim for contributing to maintenance of normal blood cholesterol levels (Commission Regulation (EU) No 432/2012). Sufficient dietary fibre intake may provide many health benefits, such as lower risk of cardiovascular disease, type 2 diabetes and colorectal cancer (see reviews by Lattimer and Haub, 2010; Mudgil and Barak, 2013). One way to increase human intake of dietary fibre is to increase intake of whole grain cereals. Another way is to replace wheat products, which are widely consumed today, with products made from cereals that naturally have a higher content of dietary fibre. For example, hulless barley contains 13.6–20.2% dietary fibre (Oscarsson et al., 1996), while wheat contains 11.5–15.5% (Andersson et al., 2013).

Cereals are generally processed before consumption, for example by bread baking, cooking or extrusion. This processing may affect the dietary fibre and starch properties, and different raw materials respond differently to processing (e.g. Baik et al., 2004). It is therefore important to study the properties of both the raw material and the product and how these are connected. This information would make it possible to choose the right raw material and process to achieve the properties desired in the product. One advantage with barley is that there are many varieties with differing composition, which makes it possible to choose suitable varieties for various processes. Another advantage is that the distribution of dietary fibre in the kernel of barley is different to that of other cereals, with a major part of the β-glucan present in the endosperm. In oats, the β-glucan is concentrated more to the subaleurone region (Miller and Fulcher, 1994).

Extrusion is a process that uses high temperature, pressure and shear forces to change the structure of a material and can be used to produce a variety of breakfast cereals and snacks from cereal grains (Eastman et al., 2001). During extrusion the processing parameters (pressure, water addition, temperature, screw speed and die shape etc.) can be varied, but the temperature normally lies in the range 90–180 °C. Varying the processing parameters can have different effects on dietary fibre (Vasanthan et al., 2002) and on other

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http://dx.doi.org/10.1016/j.jcs.2016.09.017
0733-5210/

product properties such as expansion. Another effect of extrusion is increased extractability of dietary fibres in the product compared with the raw material (Comino et al., 2016; Østergård et al., 1989; Sharma and Gujral, 2013; Vasanthan et al., 2002).

The aim of this study was to determine the total composition and content of dietary fibre and starch in kernels, sifted flour and extruded products made from sifted flour of six barley varieties selected for their differing composition and content of dietary fibre and starch. The varieties were followed through milling and an extrusion process to evaluate whether differences in the kernels persisted in the products and whether the varieties responded differently to processing.

2. Material and methods

2.1. Material

Six varieties of barley (*Hordeum vulgare* L.) were grown at a single location in southern Sweden during summer 2012. The varieties were: Gustav (reference, commercial feed variety), NGB 114602 (anthocyanin-rich variety), SLU 7 (shrunken endosperm, high β-glucan, high fructan variety), KVL 301 (low β-glucan, low fructan variety), SW 28708 (hulless, low amylose variety) and Karmosé (high amylose variety). The kernels (30 kg of each variety) were milled using a laboratory mill (Laboratoriums-Mahlautomat model MLU 202, Gebruder Bühler Maschinenfabrik, Uzwill, Switzerland), producing six fractions of sifted flour and two bran fractions from each variety. The six fractions of sifted flour were pooled and weighed, while the bran fractions were weighed separately. The laboratory mill was not optimized for milling of barley but still gave acceptable milling yields (Table 1). The sifted flour was used to make an extruded product in a twin-screw extruder (APV MPF 19/25, Baker Perkins Group Ltd, Peterborough, U.K.) with addition of 0.8% salt (based on flour fresh weight). Flour feeding rate was 50 g/min. Water addition was adjusted to give an appropriate pressure at the die and thereby expansion of each product (Table 1). The temperature in the extruder was increased in four steps (60-80-100-130 °C) from the feeding section to the die. The screw speed was 400 rpm, the residence time in the extruder was 2–3 min and the product was dried for 15 min at 80 °C after extrusion.

Before analysis, a centrifugal mill with a 0.5 mm sieve (Retsch, Hann, Germany) was used to mill the kernels, the bran and the extruded product.

2.2. Analytical methods

All samples were analysed at least in duplicate and results are reported as average values on a dry weight (dw) basis after drying at 105 °C for 16 h. Dietary fibre was analysed according to the method of Theander et al. (1995) (AOAC Method 994.13) with modifications by Andersson et al. (1999) to analyse extractable and non-extractable components separately. The content of β-glucan was analysed with a mixed-linkage beta-glucan kit (K-BGLU; Megazyme, Bray, Ireland) according to McCleary and Codd (1991) (AOAC Method 995.16). Calcofluor molecular weight distribution of β-glucan and amount of extractable β-glucan were analysed according to Rimsten et al. (2003) by high performance size exclusion chromatography (HPSEC), but with a Calcofluor concentration of 0.0025%. This technique excludes molecules smaller than 10^4 g/mol. The molecular weight of arabinoxylan was analysed by HPSEC coupled to multiple angle laser light scattering and refraction index detectors according to Andersson et al. (2009). Arabinoxylan with a retention time of 14.4–22.0 min was included in the results. Fructan content was determined with a K-FRUC kit (Megazyme, Bray, Ireland) according to McCleary et al. (1997) (AOAC Method 999.03), including pre-treatment with α-galactosidase to remove galactosyl-sucrose oligosaccharides. However, the extraction step was scaled down to 100 mg sample accurately weighed into a glass tube and 10 mL preheated deionised water for 20 min at 80 °C. The filtration step was replaced with centrifugation: 1 mL was centrifuged for 15 min at 10 600*g* and the supernatant was then used instead of the filtrate for analysis. Starch content was determined with thermostable α-amylase according to Åman et al. (1994) and amylose content was determined according to Chrastil (1987), but with solubilisation and lipid removal according to Morrison and Laignelet (1983). The content of resistant starch was determined using a resistant starch kit from Megazyme (K-RSTAR; Megazyme, Bray, Ireland), according to McCleary and Monaghan (2002) (AOAC Method 2002.02).

Table 1
Milling yield (%), amount of water added (ml/min), pressure at die (bar) and expansion (ml/g) in the extrusion process for the six barley varieties.

Variety	Milling yield	Water addition	Pressure at die	Expansion
Gustav	60	4	5.7–6.6	15
NGB 114602	48	5	5.9–6.6	14
SLU 7	40	3	3.7–6.0	10
KVL 301	53	4.5	5.1–5.8	13
SW 28708	43	2.5	3.9–4.4	22
Karmosé	47	4	5.5–6.0	13

3. Results

3.1. Starch

The proportion of starch was higher in the sifted flour (53.9–66.8%) than in the kernels (43.4–58.5%) for all varieties (Table 2), but the difference was smaller for the naked variety SW 28708 and larger for SLU 7, a shrunken endosperm variety. The starch content in the extruded product was similar to that in the flour for all varieties. The content of amylose in the starch remained

Table 2
Content of starch (% of dry weight, dw), amylose (% of starch) and resistant starch (% of dw) in kernel, flour and extruded product of the different barley varieties.

Variety	Sample	Starch	Amylose	Resistant starch
Gustav	Kernel	57.6	28	n.d
	Flour	66.8	29	trace
	Extruded	63.8	31	trace
NGB 114602	Kernel	58.5	28	n.d
	Flour	66.8	31	trace
	Extruded	64.3	32	trace
SLU 7	Kernel	43.4	30	n.d
	Flour	53.9	31	trace
	Extruded	54.4	31	trace
KVL 301	Kernel	49.8	27	n.d
	Flour	56.2	28	trace
	Extruded	54.8	28	trace
SW 28708	Kernel	55.0	1	n.d
	Flour	58.0	2	trace
	Extruded	60.2	2	trace
Karmosé	Kernel	48.7	44	n.d
	Flour	55.9	47	0.90
	Extruded	54.1	48	0.78

n.d – not determined.